

Laser Diffraction Techniques Replace Sieving for Lunar Soil Particle Size Distribution Data. B. L. Cooper¹ D.S. McKay², R.L. Fruland³ and C.P. Gonzalez¹, ¹Jacobs Technology ESCG Astromaterials Research Group, P.O. Box 58447, JE23, Houston, Texas 77258-8447, bonnie.l.cooper@nasa.gov, ²NASA Lyndon B. Johnson Space Center, Houston TX 77058.

Introduction: Sieving was used extensively until 1999 to determine the particle size distribution of lunar samples. This method is time-consuming, and requires more than a gram of material in order to obtain a result in which one may have confidence. This is demonstrated by the difference in geometric mean and median for samples measured by [1], in which a 14-gram sample produced a geometric mean of ~52 micrometers, whereas two other samples of ~1.5 grams resulted in gave means of ~63 and ~69 micrometers.

Sample allocations for sieving are typically much smaller than a gram, and many of the sample allocations received by our lab are 0.5 to 0.25 grams in mass. Basu [2] has described how the finest fraction of the soil is easily lost in the sieving process, and this effect is compounded when sample sizes are small.

Table 1. Measurements of Lunar Soil 10084

Sample	Year	Method	Mz (μm)	Median
10084, 79 [3, 4]	1970	Sieve + Coulter	82.18	83.48 [§]
10084, 80 [1]	1971	Sieve	50.71	45.82
10084, 853 (McKay, unpub- lished)	1977	Sieve + Fine- Particle Point Count	35.00	49.55
Basu* [2]	2001	Sieve	49.92	51.66
10084, 2005	2008	Laser Diffraction (H ₂ O carrier)	59.06	66.47
10084, 2006	2010	Laser Diffraction (IPA carrier)	36.15	40.43
10084, 2006	2010	Laser Diffraction (H ₂ O carrier)	33.76	30.05

* No subsample number given. [§]Recalculated from data in [2]

Current Work: Because the finest fraction of lunar dust is of increasing interest to toxicologists and to resource-utilization engineers, a method that can directly measure particles smaller than 10 micrometers is needed. Laser diffraction is an ensemble method which is capable of measuring particles from 2 millimeters to 0.5 micrometers. We have measured two sub-samples of Apollo 11 soil 10084 with this method, and find that the results are consistent in most cases with earlier sieved results in the range from 500 micrometers to 10 micrometers. The comparison is shown in Table 1 and in Figures 1 through 3.

The laser diffraction method, implemented in our laboratory with a Microtrac Bluewave instrument, pro-

vides improved resolution for the less-than 10 micrometer fraction of the soil, and confirms the suggestion by [2] that early sieve results on this soil (e.g. [1, 3]) were misleading. Sieving done on a clean bench with positive air pressure, or dry sieving with sonic sifters may deplete the finest fraction of the soil, producing particle size distributions that are inconsistent with the high maturity of this soil (I_v/FeO of 78 [5]).

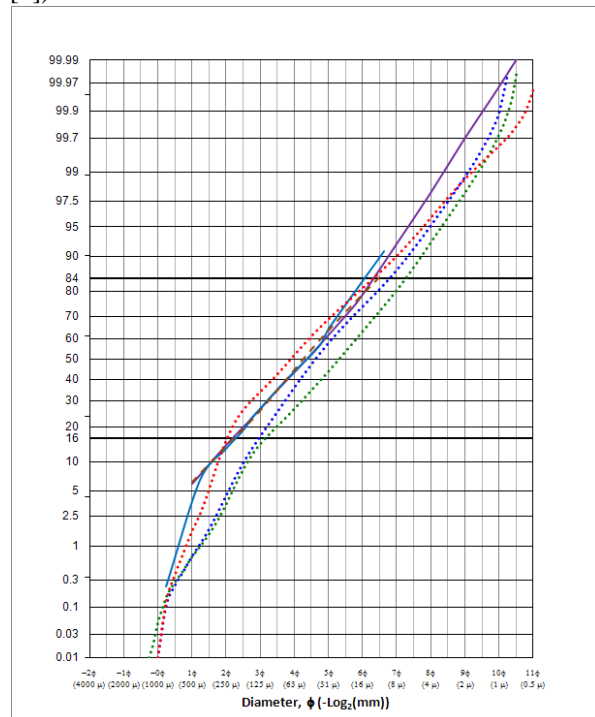


Figure 1. Measurements of Apollo 11 soil 10084. Purple: 10084,853 [6]. Brown, [2]: Light Blue: 10084, 80 [1] Dotted Red: 10084,2005 Dotted Blue: 10084,2006, in isopropanol. Dotted Green: 10084,2005 in water.

Precision in Measurements of the Finest Fractions: One method that was successful in measuring the finest fraction of lunar soils involved a point count of particles less than 20 micrometers in diameter. From these, a volume calculation provides relative percentages of particles in five size ranges (e.g 10084, 853, Figure 1 [6]). This method improved the resolution in the finest fraction beyond the capability of sieves. However, the laser diffraction method has 33 subdivisions for sizes less than 10 micrometers, providing significantly more detail.

The laser diffraction measurements suggest that a larger percentage of lunar soil 10084 is comprised of

particles in the less-than 10 micrometer region compared to previous reports. This result is plausible because the soil is not extensively manipulated in the sampling process—a 100-milligram representative sample is obtained from an allocation, and placed directly into the liquid in which it is to be measured. The sample is not agitated, and therefore the finest particles do not have an opportunity to escape.

The correspondence between the laser diffraction data and the sieve data is excellent in the range of 500 micrometers to 7 micrometers (Figure 2). When the three laser-diffraction data sets are averaged, they are again seen to correspond closely to the sieve data in this region (Figure 3).

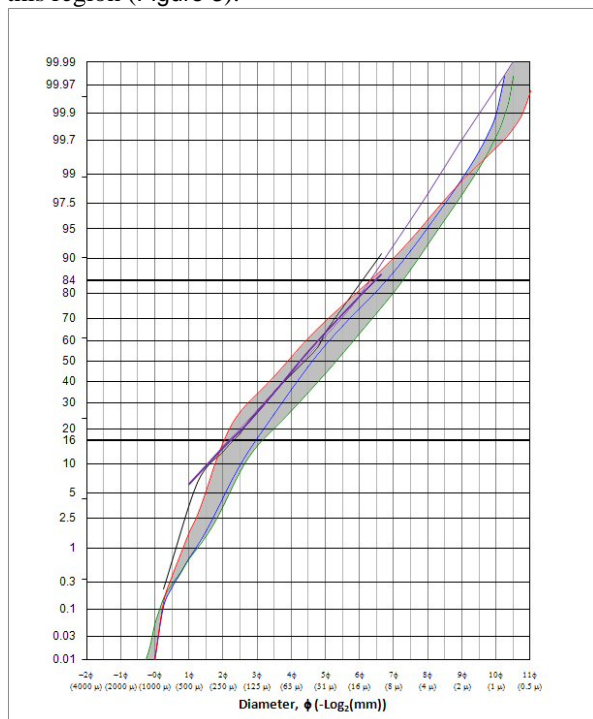


Figure 2. Laser diffraction values, in the shaded envelope, encompass the sieve data within the range of 500 micrometers to 7 micrometers.

Significance of Results: The determination of lunar soil grain size distribution using sieves was the method used in virtually all of the more than 100 analyses tabulated [4]. This technique was labor intensive, tedious and time consuming, taking as much as a week per sample. By contrast, the laser diffraction method is rapid and reproducible, taking less than half an hour to produce a complete size distribution covering hundreds of size bins and providing size data down to 1 micrometer, an impossible task for sieving. The use of this method opens the door to detailed (every few mm) grain size data collection on the existing lunar core and drive tube samples to look for detailed stratigraphic variation, possibly revealing additional

information on the development and history of the regolith. If regolith investigators standardize on this method, correlation among labs for current and future lunar samples will be possible. Furthermore, the technique should be adaptable to flight payloads sent to the lunar surface or to asteroid surfaces. Detailed grain size distribution may provide geologic and stratigraphic information not available by other techniques (chemistry or spectral properties) and should be seriously considered for future robotic missions to the moon asteroids, and Mars.

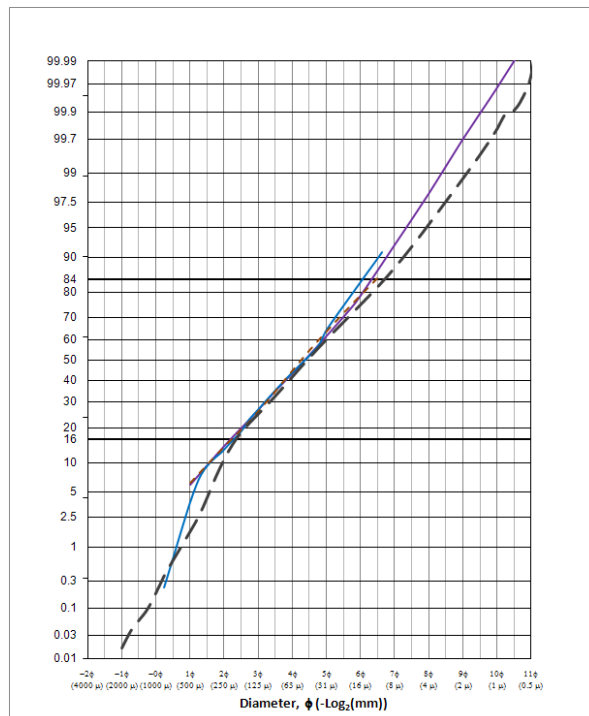


Figure 3. Averaged laser diffraction data are shown as a heavy dashed line, and coincide closely with the sieve data (colors for other data as in Figure 1).

References:

- [1] King Jr, E.A., et al. (1971) *Proc. 2nd Lunar Sci. Conf.*, 737-746.
- [2] Basu, A., et al., (2001) *Meteoritics & Planet. Sci.*, 36, 177.
- [3] Duke, M.B., et al. (1970) *Proc. Apollo 11 Lunar Sci. Conf., Geochim. et Cosmochim. Acta Suppl.*, 347.
- [4] Graf, J.C., (1993) *Lunar soils grain size catalog*: NASA Scientific & Tech. Information Prog.
- [5] Morris, R.V. (1978) *Proc. 9th Lunar & Planetary Sci. Conf.*, 2287-2297.
- [6] McKay, D.S. (1977) *Unpublished data.*